ISSUED: MARCH 11, 2021

Design of SIPs Used as Diaphragms

When using SIPs in roof and floor applications, design professionals must address two key design issues. These are (1) the ability of the SIPs to withstand gravity loads in transverse bending and (2) the ability of the SIPs to function as a diaphragm to withstand lateral loads from wind or seismic events.

Transverse Bending

The ability of SIPs to withstand gravity loads in transverse bending is well documented based on extensive laboratory tests conducted by SIPA member manufacturers through independent third-party testing laboratories. These tests have been conducted in conformance with ICC-ES AC04, *Acceptance Criteria for Sandwich Panels*, which requires that the SIPs be evaluated for both uniformly applied loads and concentrated loads. The results of these tests have been published in the form of load/span design tables in manufacturers' ICC- ESR code evaluation reports and are recognized by design professionals and code officials as being code compliant.

Diaphragms

The data for lateral load performance of SIP diaphragm systems is more limited and has remained proprietary as published in code evaluation reports held by several SIPA member manufacturers. In an effort to develop publicly available data for the SIP industry, and to better understand the performance of SIPs used as diaphragms, APA – The Engineered Wood Association; the USDA Forest Products Laboratory (FPL); and the Structural Insulated Panel Association (SIPA) conducted a comprehensive joint research study. The testing was carried out at the APA Research Center in Tacoma, WA.

The testing program involved structural testing of 12 SIP diaphragms (8' x 24' in plan) of various configurations that covered a range of key variables. These included the effects of both longitudinal and transverse SIP joints and the use of SIP screws at different spacings. The test configurations are summarized below.

1. Effect of a longitudinal SIP joint: no joint vs. one joint. This involved the test of a full 8' x 24' panel and a test with two 4' x 24' panels.
2. Effect of a transverse SIP joint: no joint and one joint. This involved the test of the full 8' x 24' panel and a test with two 8' x 12' panels.
3. Effect of both longitudinal and transverse joints: one longitudinal and one transverse joint consisting of four 4' x 12' panels and one longitudinal and two transverse joints consisting of six 4' x 12' panels.
4. Effect of using SIP screws spaced at 6 inches on center and 3 inches on center to connect the SIPs to sub framing members.

The testing of each SIP diaphragm was conducted following a monotonic procedure specified in ASTM E455 *Standard Test Method for Static Load Testing of Framed Floor or Roof Diaphragm Constructions for Buildings.* All SIPs were 8-1/4-inch in depth and a block spline was used for the joints in the top facers. The testing program goal was to evaluate (a) the capacity of a SIP diaphragm as a stand-alone structural element and (b) the capacity of SIP diaphragms connected to framing. The results of this study are reported in FPL-RP-700 *Lateral Load Performance of Structural Insulated Panel (SIP) Diaphragms* and are summarized as follows.

Structural Insulated Panel Association

www.sips.org
P.O. Box 39848, Fort Lauderdale, FL 33339
253-858-7472

Stand-alone test results: For the diaphragms tested as stand-alone structural elements, the results indicated that a shear strength difference between SIP diaphragms constructed with one segment and two segments was minimal with the maximum difference being ± 6 percent. For the diaphragms constructed with four and six SIP segments a nominal increase in shear capacity over the base SIP (no joints) of between 12 percent and 15 percent was observed. This difference was not considered to be significant based on the limited number of tests. Overall, the average peak load for all tests was 1240 lbf/ft. Using a factor of safety of 3 this equates to a shear design capacity of 415 plf.

With respect to SIP deflection correlations between ultimate deflection and number of SIP segments two distinct trends were observed. Similar to the shear capacity results the difference between diaphragms with one segment and two segments was minimal having a range in values within approximately ± 6 percent. But a significant increase in ultimate deflection was noted when the segment number was increased to four and six. This increase was 50 percent for the four segment SIP diaphragm configuration and 125 percent for the six segment SIP diaphragm configuration.

The basic conclusions from the testing of stand-alone diaphragms were (a) the effect of joints on shear capacity is minimal regardless of the number of SIP joints and (b) there is no discernible difference in diaphragm deflection between SIPs having no joints and SIP assemblies with single joints, but there is a significant increase in deflection for SIP assemblies with multiple joints. The test results also confirmed that the shear strength of stand-alone SIP diaphragms can be reasonably estimated using single fastener lateral strength values and the principles of engineering mechanics.

SIPs attached to sub framing using SIP screws: As was observed for the stand-alone diaphragms, for diaphragms using SIP screws spaced at 6 inches on center there did not appear to be a significant impact on diaphragm shear strength with a change in the number of SIP segments with a range of approximately ±10 percent between the base SIP (no joint) and SIP assemblies with single or multiple joints. Overall, the average peak load for all tests was 2220 lbf/ft. Using a factor of safety of 3 this equates to a shear design capacity of approximately 740 plf which is 80 percent greater than the stand-alone diaphragms.

With respect to correlations between ultimate deflection and number of SIP segments it was observed that there was less than a ±10 percent difference between the SIP with no joints and all other SIP assemblies with the exception of the SIP assembly with six segments. For the SIP assembly with six segments the deflection was approximately 30 percent greater than the base panel.

For the tests using SIP screws spaced at 3 inches on center the average peak load was 3545 lbf/ft which equates to a shear design load of 1180 plf. This represents an increase of 60 percent in shear capacity over the panels with screws spaced at 6 inches on center. On average, the shear strength of SIP diaphragms connected to framing with screw spacing of 3 inches on center was well-predicted using the single SIP screw lateral strength and the principles of engineering mechanics, but it was under-predicted by 14 percent to 25 percent for screw spacing of 6 inches on center. In addition, the shear capacities observed based on the limited number of tests in this study for both the diaphragms using SIP screws spaced 6 inches on center and 3 inches on center generally exceeded the values published in SIPA member manufacturer code evaluation reports.

The FPL report referenced above can be downloaded at no charge from the FPL website (fpl.fs.fed.US).

Structural Insulated Panel Association

www.sips.org
P.O. Box 39848, Fort Lauderdale, FL 33339
253-858-7472